Original Article

Hydrotherapy Reduces Arterial Stiffness in Pregnant Women With Chronic Hypertension

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Abstract

Background: Chronic hypertension (CH) and high arterial stiffness (AS) increase the risk of complications during pregnancy, such as superimposed preeclampsia and low fetal growth.

Objective: To evaluate the impact of hydrotherapy, a non-pharmacological treatment strategy, on AS in pregnant women with CH.

Methods: Cross-sectional study evaluating the effect of a standardized hydrotherapy session on AS in pregnant women with CH and controls. We used the device Mobil-O-Graph® NG to measure blood pressure (BP), heart rate (HR), and AS before and after a hydrotherapy session involving stretching, warming up, strengthening, and relaxation. The level of significance adopted in the statistical analyses was 5%.

Results: We evaluated 36 pregnant women, including 12 with hypertension (HG) and 24 controls (CG), aged 30.4 ± 4.8 years and at 29.2 ± 3.3 gestational weeks. Hydrotherapy promoted in both groups a significant reduction in AS assessed by the augmentation index at a HR of 75 bpm (AIx@75) (HG: 28.8 ± 7.3%, before; 22.4 ± 6.9%, after; p = 0.024; and CG: 29.1 ± 7.4%, before; 22.9 ± 6.6%, after; p = 0.001), as well as a reduction in HR (HG: 93.4 ± 11.8 bpm, before; 82.4 ± 10.0 bpm, after; p < 0.001; and CG: 91.4 ± 13.4 bpm, before; 81.5 ± 12.6 bpm, after; p < 0.001), but a nonsignificant reduction in BP.

Conclusion: We demonstrated that a hydrotherapy session acutely reduces AS assessed by AIx@75, and may represent a potential non-pharmacological strategy to prevent maternal and fetal complications in pregnant women with CH. (Arq Bras Cardiol. 2020; 114(4):647-654)

Keywords: Hypertension; Hydrotherapy; Pregnancy, High-Risk Ris/complications; Vascular Stiffness; Pre-Eclampsia.

Introduction

Hypertensive syndromes in pregnancy are associated with a higher risk of maternal and fetal complications. The various forms of hypertension during pregnancy cause about 14% of maternal deaths and are associated with dysfunctions affecting the newborn, such as low birth weight.[1,2] Several hypertensive syndromes occur during pregnancy, including preeclampsia, eclampsia, chronic hypertension, chronic hypertension with superimposed preeclampsia, and gestational hypertension.[3] Chronic hypertension (CH) causes 1 to 5% of all complications in pregnancy.[2]

In women with normotension or hypertension and in individuals in the general population, increased arterial stiffness (AS) has been recognized as a marker of higher risk for cardiovascular outcomes with even more significance than elevated peripheral blood pressure (BP) measured at the brachial artery (bBP).[4-6]

A portion of the pulse wave directed to the periphery is reflected back from peripheral impedance points. In healthy individuals, the reflected wave returns to the aorta during diastole. Due to aging or conditions that compromise arterial compliance, stiffer arteries reduce the transit time of incident and reflected waves. Consequently, reflected waves reach the aorta earlier, increasing central arterial pressures. The increased central pressure can be quantified by the augmentation index (Alx), defined as the percentage of central pulse pressure attributed to the reflected wave.[7] Evidence points out to Alx as a hallmark of the pathophysiology of hypertensive syndromes of pregnancy.[7] Increased Alx is recognized as a cardiovascular risk marker[5,7] and has been correlated with pregnancy complications, such as superimposed preeclampsia and fetal growth restriction, and a potentially additional future cardiovascular risk in women.[8-11]

Evidence shows a beneficial effect of regular physical activity in pregnant women with hypertension.[10,11] Aquatic physical therapy, better known as hydrotherapy, is a non-pharmacological intervention used in various clinical contexts that utilizes the properties of immersion in warm water associated with the practice of combined aerobic and resistance exercises.[12-17] However, no studies have evaluated the impact of this physical activity on AS in pregnant women with hypertension.

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In this study, we evaluated the acute effects of a standardized hydrotherapy session on AS parameters, such as AIx, in pregnant women with CH compared with a group of women with normal pregnancy. The analysis also included the heart rate (HR), systolic (SBP) and diastolic (DBP) BPs, mean BP (MBP), and peripheral (brachial artery) and central (aorta) pulse pressures (PPs).

Methods

Cross-sectional, controlled study conducted at the Aquatic Physical Therapy Clinic in Belo Horizonte (Minas Gerais, Brazil) from July 2015 to July 2016. The evaluation included 36 pregnant women, of whom 12 had chronic hypertension (thus considered to be at high risk) who were included in a hypertensive group (HG) and 24 normal-risk pregnant women who were included in a control group (CG). The diagnosis of hypertension during pregnancy was confirmed according to the 7th Brazilian Hypertension Guideline.[18] The study included high-risk and normal-risk pregnant women receiving prenatal care at Santa Casa de Belo Horizonte (MG), aged between 18 and 40 years, with a gestational age of 24 to 34 weeks, and with medical approval to perform aquatic activities, who were consecutively invited to participate in the research. Cases of multiple-gestation pregnancies, pregnant women who presented bleeding in the first and second pregnancy trimesters, smokers, and those with skin lesions or any condition that could be aggravated by immersion in heated water were excluded. The study was approved by the Research Ethics Committee of Faculdade Ciências Médicas de Minas Gerais, Brasil, (CEPCM-MG), under the opinion number 35487814.1.0000.5134. All pregnant women enrolled agreed to participate in the study and signed a free and informed consent form. For participation in the study, the group of pregnant women with hypertension should not interrupt or modify their pharmacological treatment, when previously prescribed, and during the research, these participants were encouraged to follow their health care recommendations.

Evaluation protocol

Initially, general data of the participants were collected, including age, gestational age, anthropometric measurements, personal medical history (clinical history of hypertension, diabetes mellitus, heart disease, chronic kidney disease, allergies, epilepsy), as well as information about exercise practice during pregnancy and medications in use. Vital signs of each participant were measured with the device Mobil-O-Graph® NG (IEM, Stolberg, Germany) before the participant was referred to the hydrotherapy session. After the session, clinical and hemodynamic parameters were measured once again.

Evaluation of blood pressure and arterial stiffness

Measurements of bBP, central blood pressure (cBP), and AS parameters were performed noninvasively using the Mobil-O-Graph® NG device (IEM, Stolberg, Germany) with the inbuilt ARC Solver algorithm (the ARC Solver Method, Austrian Institute of Technology). This device is an oscillometric monitor for ambulatory bBP measurement approved by the US Food and Drug Administration and the European *Conformité Européenne*, whose BP and AS detection unit has been validated by the British Hypertension Society and the American Heart Association's Council on Hypertension.[19-22] After measuring the upper limb perimeter and choosing the right cuff, measurements were carried out according to recommendations of the 7th Brazilian Guideline on Hypertension.[23] Three consecutive automated measurements were obtained, and the results were expressed as the average of the obtained values. AS was estimated by the variables AIx adjusted to a HR of 75 bpm (AIx@75) and pulse wave velocity (PWV). The equipment also provided measurements of HR, SBP, DBP, MBP, and peripheral and central PP.

Hydrotherapy session

Pregnant women from both groups, HG and CG, underwent standardized hydrotherapy sessions in a heated indoor pool with temperature between 32 and 34°C and duration of 40 minutes, with their bodies immersed up to the level of the xiphoid process.[24] Each session was divided into four 10-minute phases: stretching, warming up, strengthening, and relaxation. The first phase included three series of 30 seconds of stretching exercises of the anterior, posterior, and lateral trunk muscles. The second phase included a warm-up exercise consisting of walking at a comfortable speed based on self-assessment. The third phase consisted of upper and lower limb strengthening exercises. In the fourth phase, relaxation movements were performed.[24]

Statistical analysis

The analysis comprised the average of the three BP and AS measurements indicated by the device. Qualitative variables were presented as numbers and percentages, and quantitative variables as mean ± standard deviation. All continuous variables were subjected to the Shapiro-Wilk normality test. The comparison of means between two samples was performed by Student's *t* test; for differences in measurements before and after the intervention, the paired version was used, and for differences between groups, the version for independent samples was used. The analyses were performed using the software R, version 3.2.2 (R Foundation for Statistical Computing, Vienna, Austria). In the sample size calculated *a priori*, the significance level was set at 5% and the power at 90%, using a standard deviation of the differences in BP equal to 5.19 based on a similar previous study.[25] The detection of a difference of 5 required a total of 12 pregnant women with hypertension and 24 pregnant women in the control group, yielding a 2 to 1 ratio, the exact ratio used in our study.

Results

The sample of this study consisted of 36 pregnant women, of whom 24 (66.7%) were in the CG and 12 (33.3%) were in the HG group. The mean age was 30.4 ± 4.8 years, and the mean body mass index (BMI) was 31.7 ± 7.3 kg/m^2. At the time of the intervention, the participants' gestational age was 29.2 ± 3.3 weeks. Among the women participating in the study, 63.9% were black, 80.6% used some type of medication, and 22.2% practiced regular physical activities. There was no difference between the HG and CG in relation to race, physical activity, age, or gestational age. The HG had a higher mean BMI ($p < 0.001$) (Table 1).

Table 1 – Characteristics of the control (CG) and hypertensive (HG) groups

Variables	Entire sample (n = 36)	Control (n = 24)	Hypertensive (n = 12)	p
Age (years)	30.4 ± 4.8	30.5 ± 5.1	30 ± 4.3	0.741[T]
BMI (kg/m^2)	31.7 ± 7.3	28.1 ± 4.7	38.9 ± 6	< 0.001[T]
Race				0.719[F]
White	13 (36.1%)	8 (33.3%)	5 (41.7%)	
Black	23 (63.9%)	16 (66%)	7 (58.3%)	
Practice physical activity	8 (22.2%)	7 (29.2%)	1 (8.3%)	0.224[F]
Use of medications	29 (80.6%)	17 (70.8%)	12 (100%)	0.070[F]
Methyldopa	12 (41.4%)	-	12 (100%)	-
Multivitamin	11 (37.9%)	9 (52.9%)	2 (16.7%)	0.064[F]
Iron sulfate	6 (20.7%)	5 (29.4%)	1 (8.3%)	0.354[F]
Folic acid	4 (13.8%)	3 (17.6%)	1 (8.3%)	0.622[F]
Gestational age (weeks)	29.2 ± 3.3	29.3 ± 3.3	29 ± 3.5	0.840[T]

Note: The p values refer to Student's t test [T] for independent samples and Fisher's exact test [F]. BMI: body mass index.

Hydrotherapy promoted a significant reduction in AIx@75 in both groups, with percentage differences of 22.2% in the HG ($p = 0.024$) and 21.3% in the CG ($p = 0.001$), as shown in Figure 1. There was also a significant reduction in HR, with differences of 11 bpm ($p < 0.001$) in the HG and 9.9 bpm ($p < 0.001$) in the CG (Figure 2a). There was a trend toward a decrease in SBP after the hydrotherapy session, which was not significant ($p = 0.050$) (Figure 2b). There was no significant difference between the measurements obtained before and after the intervention for the other variables evaluated (Table 2).

In a comparison between the groups, higher values were observed in the HG compared with the CG regarding SBP, DBP, MAP, PP, central SBP, and PWV, both before and after the intervention (Table 2). However, there were no differences between groups in AIx@75 and HR values, which were variables that decreased significantly with the intervention.

No adverse events or discomforts associated with the hydrotherapy sessions were reported by the pregnant women evaluated.

Discussion

This study evaluated the impact of a hydrotherapy session on AS in high-risk pregnant women with CH compared with normal-risk pregnant women, yielding evidence unprecedented in the literature. Despite concerns about the safety of aquatic exercises during pregnancy, the procedure in our study proved to be safe for pregnant women with hypertension and controls in the third trimester of pregnancy. Barakat et al.[26] also demonstrated the safety of exercise practice among pregnant women. These authors compared the effects of exercise on pregnant women, concluding that while land exercises were more effective at preventing maternal weight gain, aquatic or combined programs involving land and water were more effective at preventing gestational diabetes.[26] Bacchi et al.,[27] evaluating 100 healthy pregnant women, concluded that three weekly sessions of aquatic activities during pregnancy prevent maternal overweight and preserve birth weight.

A meta-analysis concluded that a single isolated aerobic exercise session lasting 10 to 50 minutes at different intensities could reduce SBP by 5 to 7 mmHg, an effect that is maintained for up to 24 hours after training.[28] The magnitude of this reduction in SBP is comparable to the effect of most preferred antihypertensive drugs,[29] which presupposes a reduction in cardiovascular risk of 20 to 30%,[30] according to the conclusion of the position stand of the American College of Sports Medicine on exercise and hypertension.[31] In our study, we observed that hydrotherapy promoted a 6% reduction in SBP (139.6 ± 12.1 mmHg/130.1 ± 12.6 mmHg, $p = 0.050$) in the HG, a percentage similar to that described for other aerobic modalities but without a significant difference, probably due to the small sample size.

The BP variation in a liquid medium is considered to be predominantly affected by three components: temperature, immersion depth, and exercises during hydrotherapy.[32,33-35]

Small changes in water temperature have significant effects on heat loss or retention in the immersed patient because water has a thermal conductivity 25 times higher than air.[35] Additionally, the vasodilating effects of contact with heated water are well established.[36] The temperature of the water has a significant influence on maternal and fetal hemodynamics, and temperatures above 38.9°C have even been shown to cause potential embryonic or fetal deleterious effects.[37]

Despite using different parameters regarding the temperature of the water, duration, and level of immersion, there are reports of decreased BP induced by immersion.[38-40] Immersion causes reflex cardiovascular adjustments, such as redistribution of body fluids due to hydrostatic pressure, which leads to increased central blood volume, decreased HR, and increased systolic volume, cardiac output and natriuresis.[35]

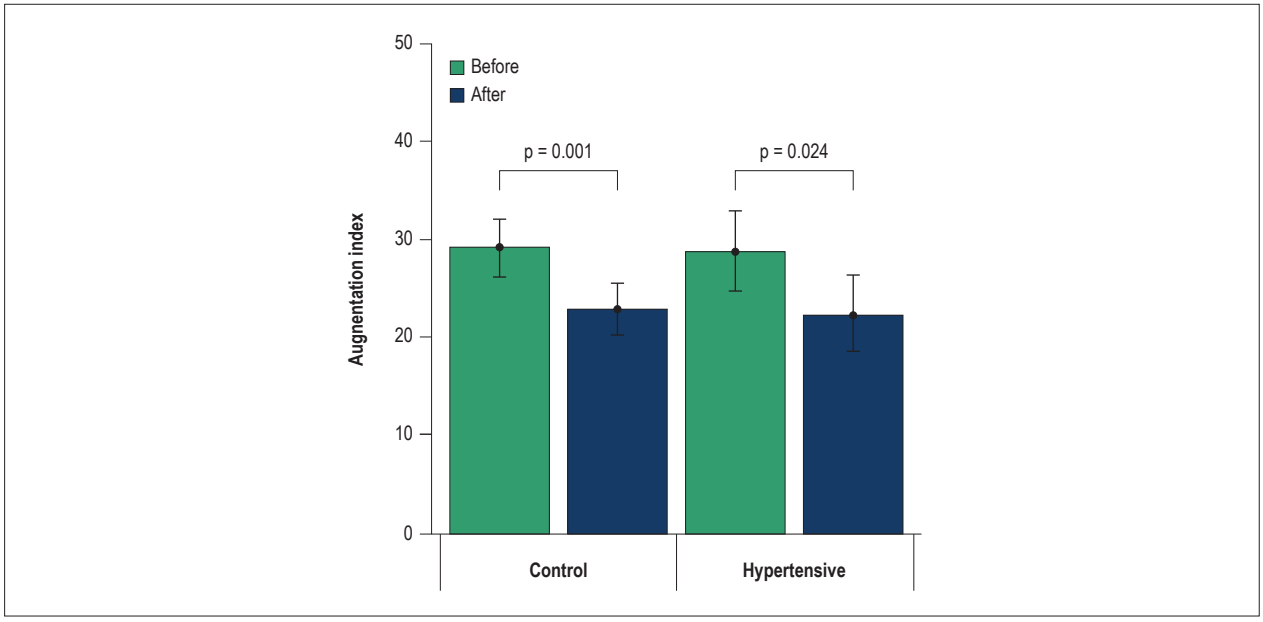

Figure 1 – *Reduction in the augmentation index adjusted for a heart rate of 75 bpm (AIx@75) (%) before and after a hydrotherapy session in the control (CG) and hypertensive (HG) groups.*

Table 2 – Longitudinal and intergroup comparison of the measures evaluated

Variables	Group	Before	After	P
Systolic blood pressure	Control	112 ± 7.6	110.8 ± 10.3	0.404
	Hypertensive	139.6 ± 12.1	130.1 ± 12.6	0.050
(mmHg)	P	< 0.001	< 0.001	
Diastolic blood pressure	Control	69.9 ± 6.9	70.1 ± 5.9	0.912
	Hypertensive	85.6 ± 9.9	82 ± 5.5	0.160
(mmHg)	P	< 0.001	< 0.001	
Mean blood pressure	Control	89.3 ± 6.5	88.7 ± 7.5	0.625
	Hypertensive	111.2 ± 9.6	103.5 ± 8.7	0.103
(mmHg)	P	< 0.001	< 0.001	
Pulse pressure	Control	41.6 ± 6.9	40.2 ± 7	0.320
	Hypertensive	53 ± 9.4	47.9 ± 10.2	0.190
(mmHg)	P	0.002	0.033	
Central systolic blood pressure	Control	102.9 ± 7.1	101.3 ± 9.3	0.276
	Hypertensive	126 ± 9.9	119.7 ± 8.9	0.161
(mmHg)	P	< 0.001	< 0.001	
Heart rate	Control	91.4 ± 13.4	81.5 ± 12.6	< 0.001
	Hypertensive	93.4 ± 11.8	82.4 ± 10.0	< 0.001
(bpm)	P	0.650	0.819	
PWV	Control	5.1 ± 0.3	5.1 ± 0.4	0.469
	Hypertensive	6 ± 0.4	5.8 ± 0.5	0.151
	P	< 0.001	0.001	
AIx@75 (%)	Control	29.1 ± 7.4	22.9 ± 6.6	0.001
	Hypertensive	28.8 ± 7.3	22.4 ± 6.9	0.024
	P	0.903	0.852	

Note: The p values refer to Student's t test for paired samples in the columns and independent samples in the rows. PWV: pulse wave velocity (m/s); AIx@75: augmentation index adjusted for the heart rate of 75 bpm in %.

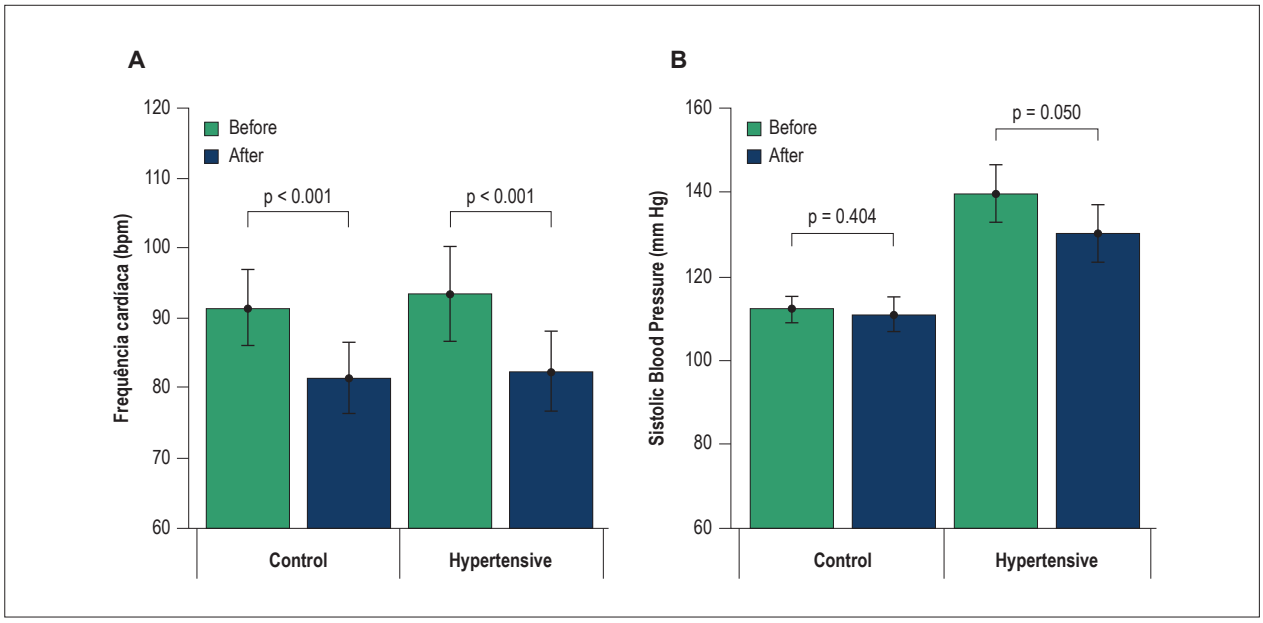

Figure 2 – *Variations in heart rate (A) and brachial (peripheral) systolic blood pressure (B) before and after a hydrotherapy session in the control (CG) and hypertensive (HG) groups.*

Finkelstein et al.[41] found a significant reduction in HR and BP among pregnant women immersed up to the level of the xiphoid process, as done in our study. The authors suggest that this decrease may be related to decreased plasma renin activity and increased atrial natriuretic peptide concentration in response to blood volume expansion in water. Elvan-Taşpınar et al.[42] compared the effect on central and peripheral hemodynamics of simple immersion in water at 35°C for 3 hours in a small sample divided into 3 groups: normal-risk pregnant women, pregnant women with preeclampsia, and nonpregnant women. The authors observed a transient reduction in HR, DBP, and total peripheral resistance.[42]

Still, there is evidence that exercise produces a significant additional cardiovascular impact during pregnancy and in other clinical conditions.[36,43-45] In a study by Ward et al.[25] evaluating the impact of aquatic physical therapy in normotensive pregnant women, no significant changes in post-immersion BP compared with pre-immersion BP were observed; however, a significant reduction in MBP in the post-exercise phase was noted. Coelho et al.[45] demonstrated a significant reduction in SBP, DBP, and MBP among pregnant women without hypertension 45 and 60 minutes after an aquatic exercise session.

We conclude that there is sufficient evidence showing that aquatic physical therapy promotes an impact on BP components through an interaction of the effects of its three fundamental elements: temperature, immersion, and exercise. Although still an area with limited research, these studies demonstrated the effects of hydrotherapy on BP in normal individuals, pregnant or not, opening up to possibilities of intervention in hypertensive pregnant women. However, there is no previous evidence in the literature about the impact of hydrotherapy on AS in pregnant women with CH, a parameter evaluated in our study.

Measurements of AS, such as the ones expressed by AIx@75, as well as central SBP (cSBP), have been shown to be more sensitive independent predictors of future cardiovascular events compared with conventional bBP in various clinical conditions[46-49] and in pregnancy.[50,51] The AIx@75 has been shown to be independent of bBP during pregnancy, indicating that the AIx@75 measurement may reflect arterial compliance during pregnancy.[50] A close inverse association between the newborn's birth weight and AS of normotensive pregnant women has also been demonstrated, indicating that abnormal pressure-wave reflection may affect fetal growth even in the absence of hypertension.[51] Additionally, increased AIx@75 and cSBP have been observed in women with newly diagnosed preeclampsia.[52] Khalil et al.[9] demonstrated a change in pressure-wave reflection after the first trimester of pregnancy in women developing preeclampsia. Yinon et al.[10] demonstrated increased AIx@75 percentages up to 6 to 24 months after delivery in pregnant women with a history of intrauterine growth restriction and/or early-onset preeclampsia. Tomimatsu et al.[53] showed that abnormal pressure-wave reflection during the 26 to 32 gestational weeks correlated more strongly with birth weight than conventional bBP, to the extent that AIx@75 was the only hemodynamic parameter significantly elevated in pregnant women who developed fetal growth restriction. Such evidence corroborates our findings of decreased AIx@75 without significant bSBP reduction with hydrotherapy. We demonstrated in our study that a single hydrotherapy session was able to decrease AIx@75 acutely by 22.2% and 21.3% in pregnant women with CH and controls, respectively. The intervention proved to be safe and may represent a potential non-pharmacological therapeutic strategy for pregnant women with CH in preventing maternal and fetal complications.

Conclusion

In a pioneering study, we demonstrated that a hydrotherapy session is able to promote a reduction in AS assessed by AIx@75 in high-risk pregnant women with CH in the third trimester of pregnancy.

Limitations

Our study has potential limitations. The number of patients evaluated was relatively small, even though it respected the sample size calculated *a priori* for a proper evaluation of the hypothesis. Also, we recognize that the study was conducted at a single center and, for greater sample homogeneity, was restricted to the gestational period of 24 to 34 weeks; therefore, it may not represent the entire universe of pregnant women with CH. We only evaluated the acute effect of a single hydrotherapy session; however, being safe and potentially beneficial, there is a promising possibility of amplification of these initial results if the intervention is performed more continuously in this patient population. We hope that similar research can be conducted in a larger number of patients of different ethnic and social characteristics and in other locations to replicate and broaden our findings.

Author contributions

Conception and design of the research, acquisition of data analysis and interpretation of the data: Linhares GM, Machado AV, Malachias MVB; statistical analysis, writing of the manuscript and critical revision of the manuscript for intellectual content: Linhares GM, Malachias MVB.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Faculdade de de Ciências Médicas de Minas Gerais under the protocol number 35487814.1.000.5134 . All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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